BRL
111

File Copy

491790

BRL

-- JUL 1996

REPORT NO. 111
JULY 1938

AERODYNAMIC NOMENCLATURE AND FORMULAS, CONVERSION FACTORS AND DRAG FUNCTIONS

H. P. Hitchcock

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

Ballistic Laboratory
Report No. 111

HPH/emh
Aberdeen Proving Ground, Md.
July 18, 1938

AERODYNAMIC NOMENCLATURE AND FORMULAS, CONVERSION FACTORS AND DRAG FUNCTIONS.

In the treatment of projectile aerodynamics, the Proving Ground in the past has employed certain terms and definitions. It has been discovered that many of them are at variance with current aerodynamic usage. The present paper proposes a system which will be more nearly in accordance with it.

Part I is the proposed list of terms. Most of the symbols agree with those in Chapter X of Lt. Col. T. J. Hayes' "Elements of Ordnance", which is now being published.

Part II gives some important formulas, which indicate the relations among the symbols and serve to define certain terms. This part also indicates the assumed standard atmospheric conditions at the surface of the earth.

Part III contains conversion factors pertaining to the new and old symbols, and also to the symbols used by R. H. Fowler, E. G. Gallop, C. N. H. Lock, and H. W. Richmond in "The Aerodynamics of a Spinning Shell" (Phil. Trans. Royal Soc. London. A 221: 295-387). In this report, the new symbols pertain to values expressed in consistent units; the old symbols, in practical units.

Part IV gives the forms of the six types of projectile for which drag functions have been tabulated. Whenever a symbol denotes a particular value pertaining to one of these types, the corresponding number will be added as a subscript.

CONTENTS

Part I	Aerodynamic Nomenclature	Page 2
Part II	Aerodynamic Formulas	Page 4
Part III	Conversion Factor	Page 5

PART I

AERODYNAMIC NOMENCLATURE

Symbol	Nomenclature	Unit
R	Total air resistance	$lb.ft/sec^2$
D	Drag	"
L	Cross wind force	"
N	Normal force	"
M	Moment of R about C.G.	$lb.ft^2/sec^2$
Hw	Yawing moment	"
f	Yawing moment damping factor	sec^{-1}
κ	Cross wind force damping factor	"
w	Angular velocity of axis of shell	"
ρ	Air density	lb/ft^3
v_o	Muzzle velocity	ft/sec
v	Velocity of projectile relative to gun	"
u	Velocity of projectile relative to air	"
w	Velocity of air relative to gun	"
a	Velocity of sound waves in air	"
d	Caliber	ft
m	Mass of projectile	lb
i	Form factor	1
j	Drift factor	1

Symbol	Nomenclature	Unit
$1/n$	Twist of rifling	1/cal.
N	Spin	sec^{-1}
A	Axial moment of inertia	$lb.ft^2$
B	Transverse moment of inertia	"
p	Moment of inertia factor	1
s	Stability factor	1
g	Distance from base to center of gravity	cal.
h	Distance from base to center of pressure	"
λ	Cross wind force factor	$lb.ft/sec^2$
ν	Normal force factor	"
μ	Moment factor	$lb.ft^2/sec^2$
k	Retardation coefficient	ft^{-1}
c_1	Cross wind factor	"
c^2	Couple factor	ft^{-2}
C	Ballistic coefficient	lb/ft^2
C_L	Drift coefficient	sec^3/ft^2
K_D	Drag coefficient	1
K_L	Cross wind force coefficient	1
K_N	Normal force coefficient	1
K_M	Moment coefficient	1
K_H	Yawing moment coefficient	1
G	Drag function	ft/sec
Q	Drift function	sec^2/ft^2

Symbol	Nomenclature	Unit
δ	Yaw	deg.
φ	Orientation	"

PART II

AERODYNAMIC FORMULAS

$R = (D^2 + L^2)^{1/2}$

$D = \rho d^2 u^2 K_D = kmu^2$

$L = \lambda \sin \delta$

$\lambda = \rho d^2 u^2 K_L = \kappa\, mu = c_1 mu^2$

$N = \nu \sin \delta = D \sin \delta + L \cos \delta$ (Normal force)

$\nu = \rho d^2 u^2 K_N$

$M = (h - g) dN = \mu \sin \delta$

$\mu = \rho d^3 u^2 K_M = c^2 B u^2$

$K_M = (h - g) K_N$

$N = 2\pi v_o / nd$ (Spin)

$$s = \frac{A^2 N^2}{4B\mu} = \frac{A^2 N^2}{4B\rho d^3 u^2 K_M} = \frac{\pi^2 A^2}{\rho n^2 d^5 B K_M} \text{ (for } u = v_o\text{)}$$

$w = (\dot{\delta}^2 + \dot{\varphi}^2 \sin^2 \delta)^{1/2}$ (Angular velocity of axis)

$H = \rho d^4 u K_H = fB$

$G = D/\rho d^2 u = u K_D$

$Q = K_L / K_M u^2$

$C = m / id^2$

$C_L = n / 2\pi g p j v_o$

$p = A / md^2$

Standard atmospheric conditions at surface;

Barometric pressure: 750 mm Hg (29.53 in Hg)

Temperature: 15° C(59°F)

Relative humidity: 78%

Density: 1.2034 kg/m^3 (0.07513 lb/ft^3) (525.9 gr/ft^3)

Velocity of sound: 341.46 m/sec (1120.27 ft/sec)

PART III

CONVERSION FACTORS

New coefficients: non-dimensional, with d in ft, ρ in lb/ft^3

Old coefficients: practical units, with d in in. ρ relative to standard.

Fowler's coefficients: non-dimensional, with radius in ft. ρ in lb/ft^3.

Symbol	New	Old	Fowler's
d (ft) =	$\frac{d\ (ft)}{1}$	$\frac{d\ (in)}{.08333}$	$\frac{r\ (ft)}{2}$
d (in) =	12	1	24
r (ft) =	0.5	.04167	1
ρ (lb/ft^3) =	$\frac{\rho\ (lb/ft^3)}{1}$	$\frac{\rho\ (relative)}{.07513}$	$\frac{\rho\ (lb/ft^3)}{1}$
ρ (relative) =	13.31	1	13.31
	K_D	C_R	f_R
K_D =	1	1916.8	.25
C_R =	52.17×10^{-5}	1	13.04×10^{-5}
f_R =	4	7667	1
	K_L	C_λ	f_L
K_L =	1	1916.8	.25
C_λ =	52.17×10^{-5}	1	13.04×10^{-5}
f_L =	4	7667	1

Symbol	New	Old	Fowler's
	K_N	C_ν	f_N
K_N =	1	1916.8	.25
C_ν =	52.17×10^{-5}	1	13.04×10^{-5}
f_N =	4	7667	1
	K_M	C_μ	f_M
K_M =	1	$.2300 \times 10^{5}$	.125
C_μ =	4.348×10^{-5}	1	$.5435 \times 10^{-5}$
f_M =	8	1.840×10^{5}	1
	K_H	C_H	f_H
K_H =	1	2.760×10^{5}	.0625
C_H =	$.3623 \times 10^{-5}$	1	$.02264 \times 10^{-5}$
f_H	16	44.16×10^{5}	1

PART IV

DRAG FUNCTIONS

Type Proj.	Drag Function New Symbol	Drag Function Old Symbol	Base	Point
1	G_1	G	Square	About 2 cal. radius ogive
2	G_2	J	6° boat-tail	Long ogivo-conical head
3	G_3	J_3	Square	Scovill fuze Mark III
4	G_4	J_4	7.5° boat-tail	Long P.D. fuze Mark III
5	G_5	J_5	7.5° boat-tail	Short P.D. fuze Mark V
6	G_6	J_6	Square	7 cal. radius ogive

Note: The tabulated drag functions are in practical units.

Multiply by 1916.8 to obtain

$$G = uK_D$$

where K_D is non-dimensional.

H. P. Hitchcock

H. P. Hitchcock